

**The Laws of Heredity--Their
Definite Meaning and
Interpretation**

**The Second
of a Series of Monographs
on the Improvement of
the Human Plant**

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**ISSUED BY
THE LUTHER BURBANK SOCIETY
SANTA ROSA, CALIFORNIA**

FOREWORD

Heredity is more of a factor in human life than in plant life—more of a menace—more of a hope.

And nothing in the world of living things responds so quickly to new environments as the human mind—child and adult.

The great value of Luther Burbank's work lies in blazing the path of the application of the forces of heredity and environment to the improvement of the human plant—to the production of better races, better nations, better communities, better families, better individuals.

Having completed the classification of Mr. Burbank's Records as applied to plant life, The Luther Burbank Society now proceeds to the larger task of interpreting the forces of heredity and environment toward the betterment of the human plant through a series of monographs, the titles of which are given on the last page, the second of the series appearing herewith.



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THE LAWS OF HEREDITY -- THEIR
DEFINITE MEANING AND
INTERPRETATION

IT IS traditional that one cannot gather grapes from thorns nor figs from thistles. The tradition embodies, by implication, the essence of the great central laws of heredity. This law is stated even more explicitly in the colloquial phrase "like produces like."

The sum and substance of the matter is that each and every living organism, be it vegetable or animal, tends to reproduce its own kind, and if we would get at the fundamental laws of heredity we have but to follow up the clew that this familiar fact gives.

We may see the principle illustrated to best advantage, perhaps, if we consider the lowly single-celled organisms, of which bacteria furnish a familiar type. These creatures, observed under the microscope, are seen to multiply by division,

a single bacterium splitting to form two bacteria, each of which presently grows to the dimensions of the original parent, and then repeats the process of division.

Such a process of multiplication obviously passes on the substance of an organism to its descendants in so definite and tangible a way that there is nothing mysterious at all about the observed fact that children are closely comparable to the parent. It is inconceivable that they should be otherwise under the circumstances. The basal fact of heredity, then, observed thus as it were at its source, seems not in the least mysterious, but a mere matter of fact.

When we reflect that complex higher organisms are made up of groups of cells aggregated and differentiated to perform specialized functions, and that all growth takes place through cell division, it will be clear that the distinction between the single-celled organism and the complex higher organism is not as radical as might at first thought appear. Each individual even of the highest forms of life, including man himself, begins existence as a single cell and grows and develops only through the countless redivisions of that cell.

There is, however, a highly important modification to be noted in the fact that the cells of the

higher organism become differentiated into divergent groups, capable of performing different functions. And, from our present standpoint, the thing to be particularly noted is that the tissue serving the purpose of reproduction of the species is segregated; and that this segregation takes place, in the case of higher animals, at a very early stage of the embryonic development of the individual.

The Continuity of the Germ-Plasm

The full significance, from the standpoint of heredity, of this segregation of the germ-plasm has been appreciated only within comparatively recent years. It was not until Professor August Weismann made special studies in this field, about thirty years ago, that the subject prominently attracted the attention of biologists.

Weismann had been struck by the fact that single-celled organisms, owing to the character of their reproduction by division, are, as he phrased it, "potentially immortal." They do not normally die, but rejuvenate themselves by division, a given individual becoming two, and these two presently becoming four, and so on in an unending geometrical progression, in which the descendants of any generation whatever might be regarded as representing the divided substance and personality of the original ancestor.

Weismann made application of this thought

to the cells constituting the germ-plasm of the higher organisms. These, he said, pass on their substance and hence their potentialities from generation to generation much as does the protozoan; and this fact of the continuity and virtual immortality of the germ-plasm furnishes the simple and obvious explanation of the observed facts of hereditary transmission of qualities from one generation to another.

In each new generation, a certain number of cells are differentiated to form body-plasm, and ultimately develop to produce the entire organism with its varied members and bodily organs; but the remaining and essential portion of the germ-plasm maintains its integrity as germ-plasm, dividing to produce cells of its own kind, even as a bacterium or an amoeba divides, and constituting an unbroken series of germ-cells linking the earliest ancestor of any line with the remotest descendant.

Parent and child are thus sprung from the same germinal stream, and in the broadest view they are not to be regarded as mother and daughter but rather as sisters of the same fraternity.

The child has the qualities and characteristics of its parent not through any occult law of transmission, but because they both draw their qualities from the same germinal stream — the perennial

stream of the ancestral germ-plasm.

It is important to get this idea of the continuity of the germ-plasm clearly in mind, for it furnishes the clew to a clearer understanding of the mysteries of heredity than would otherwise be possible.

Modification of the Germ-Plasm

It must at the same time be clearly borne in mind, however, that the stream of ancestral germ-plasm, which thus serves as the carrier of hereditary capacities from generation to generation, is not entirely beyond the reach of external influence, and does not remain absolutely unmodified throughout indefinite periods of time.

Even the bacterium changes its constitution somewhat in response to the conditions of temperature and nutriment in which it finds itself. By altering the medium and thus the food in which bacteria grow, it has been found possible to change their constitution so markedly that virulent types become relatively innocuous in the course of a few generations. Recent experiments suggest that the same thing may be accomplished by treating bacteria with ultra-violet rays, not sufficiently intense to destroy their vitality.

In a word, very marked modifications in the constitution of the single-celled organism may be produced by altered conditions of environment.

And these modifications, are as a matter of

course, passed on to the descendants of the bacterium, inasmuch as these descendants constitute, essentially, portions of the parent form.

Exactly the same thing applies to the allied process of reproduction of the germ-plasm cells of the higher organism. Modified conditions of environment — changed conditions of temperature and of nutrition — may in some cases modify them, and such modifications will be transmitted to their offspring.

It is obvious that if such were not the case there could be no change in the structure or constitution of any given line of organisms from the remotest ancestor to the most recent descendant; inasmuch as the hereditary and permanent alterations of the body-plasm are contingent — according to hypothesis — upon modifications of the germ-plasm.

But as nowadays it is fully admitted that all forms of life have undergone change in the past — higher forms evolving from lower ones through modification — it is obvious that each stream of ancestral germ-plasm must have been more or less subject to influences that modify it.

As much as this at least is admitted by every biologist, whatever his view toward the allied question of the heritability of modifications that effect the body-plasm of an individual rather than

the germ-plasm — a question, by the way, that will claim our attention in another connection, but which need not becloud our vision at the moment.

It must be understood, however, that the modifications that can be introduced in the germ-plasm in any given organism, through whatever environmental changes, are relatively slight as contrasted with the totality of qualities of that germ-plasm.

It is inconceivable, for example, that the germ-plasm of a brier should be so modified that its offspring will be bearers of grapes; or that the germ-plasm of a thistle shall become so transformed that the body-plasm sprouting from it in the next generation shall produce figs — to revert to the familiar illustration with which we set out.

To be sure, the vine that bears grapes and the tree that bears figs were doubtless originally as different from their present states as they still are different from thorns and thistles, but the gradations of modification through which the transformation has been brought about were infinitesimal in any pair of generations and have produced their effects only through the cumulative influence of myriads of generations.

If really radical transformations could be wrought in the germ-plasm of any organism in a brief period of time, the whole organic world

would be topsy-turvy and there would be no laws of heredity to discuss — at least those laws would be something quite different from what they are.

Let us, then, supplement our idea of the continuity of the germ-plasm with the thought that this germ-plasm may be modified from time to time, but that the amount of modification permissible within any limited period is infinitesimal in comparison with the sum total of the qualities of the germ-plasm itself; which qualities, it may be added, represent the aggregate influence of past environments throughout vast periods of time.

Luther Burbank has a capital phrase to the effect that “heredity is the sum of all past environments.” The import of the phrase becomes perhaps clearer if we think of it in connection with this picture of the ancestral germ-plasm — the tangible and definite series of cells directly linking every individual of any generation with the entire series of its direct ancestors.

Chicken Versus Egg

When we consider the germ-plasm in this light, its transmission of hereditary qualities seems in a sense simple and unavoidable.

But if we consider the matter a little more attentively it will appear that the germ-cell retains no small measure of mysteriousness. We agreed that there was nothing mysterious about the fact

that the single-celled organism — say the bacterium — transmits its qualities, inasmuch as its entire body is bisected. But, although we have likened the germ cells to a single-celled organism—which in point of fact it externally resembles—we cannot proceed far without noting the vital fact that the germ cell carries the potentialities not merely of other germ cells like itself, but of body cells in endless profusion that go to make up the complex organism — let us say, of a tree or of a man.

How is it conceivable that a germ cell of microscopic size shall carry forward such potentialities, and carry them so definitely that they predetermine with absolute accuracy the form of every leaf on the tree, or the color of the eyes, the complexion, and the mental qualities of the man?

As to that, no one can give a really valid answer. That the germ cell *does* convey these potentialities is familiar matter of fact. *How* it can convey them seems at first thought absolutely incomprehensible. But philosophers in all ages have puzzled over the matter, and there have been various theories put forward in attempted explanation.

There was, for example, a theory that gained popularity a few centuries ago to the effect that all the individuals that are to descend (in success-

ive generations) from any given germ cell exist pre-formed in that cell. In a figurative sense, this fact might be said to be axiomatic. But the advocates of the theory declared that it was true in a literal sense also.

Out of this thought-tangle arose the famous quibble as to which first existed — the chicken or the egg.

Of course there was not the slightest scintilla of proof of any such mysterious engulfing of infinite numbers of future organisms in the microscopic cell. And, equally, of course, the theory did not long persist.

Mechanism of the Germ-Cell

Nevertheless, it is interesting to attempt to visualize conditions, even when the conditions themselves lie beyond the limit of microscopic vision. And when the germ-cell is thus visualized, one is forced to conceive of it as made up of infinitesimal particles of matter that in some way carry pre-formed the future organism that may grow from it. No one nowadays, however, supposes that this aggregation of infinitesimal particles in the germ cell represents a replica of an adult organism. The conception is merely that there are particles of matter to represent each tissue or organ of the future organism, and that these are in some way so mutually disposed as to

pre-determine the future relations of the organs that will develop from them.

The modern physicist makes accurate studies of the sizes of molecules and atoms and of their numbers in a particle of matter comparable to the smallest germ cell, that enables us to comprehend how very complex a structure this germ cell may really be.

He tells us, for example, that there lies at the heart of the germ cell a nucleus of infinitesimal size, yet his microscope reveals various physical structures within the nucleus which he calls "chromosones" because they are readily colored by stains. He believes that these "chromosones" have to do with the transmission of characters, yet he knows that they themselves must be enormously complex; and he makes calculations which show that these chromosones, infinitesimal though they be, are made up of billions of atoms. The very smallest particle of matter that the microscope reveals is estimated to contain "many times twenty billion atoms."

So the germ cell may be in reality an enormously complex organism, containing thousands of particles, each one of which is made up of millions of atoms.

Such a computation, while it to some extent satisfies the mind as giving tangibility to the sub-

ject, does not in any proper sense fathom the mystery. It shows us that the germ cell may be indefinitely complex; but it does not explain to us how its aggregated particles — which themselves are all grouped within the compass of a single microscopic cell — can definitely determine the size and form and color and peculiarities of the future organism into which that cell may grow.

In a word, the ultimate mystery of the transmission of traits through heredity, which is involved in the mystery of every higher organism, is an unsolved enigma which challenges the profounder insight of the future investigator. Here we must be content to take the facts of heredity for granted, and to point out the *modus operandi* of inheritance without attempting to fathom its precise meanings.

In a word, the mystery of heredity is linked with the mystery of life itself, and the two mysteries await a common solution.

The Facts of Heredity

The facts of heredity, considered in detail, seem enormously intricate, yet they may be reduced to a few comparatively simple general classes. Indeed the broad fundamental fact that each organism tends to reproduce its qualities in its offspring may be said to be the one all-compassing fact that includes every minor detail of

hereditary transmission.

The full meaning of this great central fact of heredity was perhaps most comprehensively interpreted by Professor Ernst Haeckel, when he formulated his so-called "gastraea" theory, in accordance with which each individual organism tends in the course of its development to reproduce the ancestral forms through which the race has passed in its evolutionary progress.

Thus the human embryo is at first a single cell and it passes in its embryonic development through stages in which it resembles such lower orders as fish and amphibia and lower mammals before it assumes the proportions and characteristics of the human being.

The characters, are, of course, slurred over, and the reproduction of racial history is at best a blurred and epitomized one, yet the fact that the embryo does pass through such varied transformations, and that these at least roughly outline the racial history, is a highly interesting and important one, and may be said to exemplify the fundamental law of heredity in the most comprehensive way.

It is obviously a mere detail within this general law that an adult individual should sometimes develop a characteristic or an anomaly of some organ or tissue at the same age when the

same characteristic or anomaly was manifested by a parent. Examples in point are furnished by those not unfamiliar cases in which a cancerous growth develops at about the same age in parent and offspring, or in which a mental aberration similarly manifests itself.

Such manifestations of heredity are spoken of as "homochronous", but the big word scarcely adds anything to the observed facts.

The same may be said of the words "homotic" and "heterotopic" heredity, sometimes employed to express the fact that an inherited anomaly — say a tumor — may appear in the same tissues of the body of parent and offspring (homotic), or in another case in different tissues (heterotopic).

The fact is, as regards this particular matter, that a tendency to the development of a tumor may be inherited, but that the precise location of the tumor may perhaps be determined by the extraneous circumstances — say a local irritation.

The inheritance of special abnormalities of a precise and definite character — say a lock of white hair located on a particular part of the head, as a typical example — is likely to arouse surprise and to call forth comment on the mysteries of inheritance; yet rightly considered such a phenomenon is no more remarkable than the inheritance of all the ordinary characteristics that lead to

what is familiarly spoken of as family resemblance.

No one is surprised that the eyes or hair or complexion or stature or shape of nose or habits of mind in any individual strikingly resemble the same qualities of the individual's father.

In other words, the broad general facts of heredity are accepted as matters of fact without seeming to call for special comment. Stated otherwise, this is no more than saying that no one is surprised that grapes grow on grape vines and figs on fig trees. We would be astounded were the conditions reversed; and this evidences the almost axiomatic character of the great fundamental law of heredity, and its universal acceptance as a part of common knowledge.

Mingling Modified Germ-Plasms

In all this, then, we are expositing the idea that the racial germ-plasm conveys the record of past environments and pre-determines the characteristics and qualities of the organism that may grow from that germ-plasm. As thus far viewed, therefore, the facts connoted in the familiar phrase "like parent, like child" are scarcely more mysterious than the fact that successive cups of water dipped from the same stream should be like one another.

But there is a vastly complicating fact which

we have thus far purposely ignored — the familiar fact, namely, that each higher organism is not the offshoot of a single parent but a product of the union of two parents.

Be it plant or animal, every individual above the very lowest strata of organic life owes its being to the union of two germ cells. It represents the commingling of two strains of racial germ-plasm. Pollen grain unites with ovule in the case of the plant; sperm-cell with ovule in the case of the higher animal; and each type of cell conveys its own coterie of hereditary potentialities.

This is the essential and primary fact that complicates the entire situation. The fact of double parentage is one that will be seen at a glance to remove all simplicity from the formula "like produces like." For no two individuals are precisely alike; no two cells of the germ-plasm carry precisely the same ancestral traits.

The briefest consideration will suggest some at least of the complications that necessarily result when more or less divergent germ-plasms are commingled.

Of course, if two ancestral germ-plasms are too widely divergent they cannot commingle at all. The two organisms are then said to be mutually infertile. This was formerly supposed to be the case with most different species. Indeed the test

of capacity to interbreed with the production of fertile offspring was long considered to be the best test of specific identity. Nowadays we know, thanks largely to Mr. Burbank's experiments, that this test cannot be fully relied upon. Nevertheless, it is clear that only species that are somewhat closely related can interbreed.

Even where union takes place between members of the same species, however, there are sure to be some divergent traits that are more or less in conflict. It may chance even that there are numerous minor traits that are mutually antagonistic.

For example, to take the simplest and most familiar case, animals of the same species may differ radically in color. One guinea pig may be jet black and another pure white. It is obvious in such a case that the offspring cannot be like both parents in color.

Here, then, is a complication that introduces an element of uncertainty into the otherwise simple law of heredity.

It is perhaps not too much to say that all questions of heredity center chiefly around the inquiry as to just what are the mutual relations of more or less antagonistic qualities when commingled through cross-fertilization.

Hybridization and Variation

At an early stage of his work in plant develop-

ment, Mr. Burbank discovered that it is possible to hybridize species that are seemingly quite divergent, and that the results are often very striking. He brought together plants from different continents, and found that in many cases they would interbreed.

For example, he hybridized the Siberian raspberry with the California dewberry, producing a remarkable new fruit which he called the Primus berry.

Everyone is familiar with the conspicuous differences between a raspberry and a blackberry. To mention only one of them, the raspberry leaves its receptacle on the vine when picked, while the blackberry retains the receptacle as part of the fruit. It at once becomes an interesting question as to how these divergent qualities are harmonized in hybridized offspring.

In point of fact, inspection of the hybrid Primus berry shows that each parent strove to transmit its own peculiarity as regards this matter of the receptacle. The result is that the Primus berry, if plucked just at the moment when it is approaching maturity, acts like a blackberry, bringing away the receptacle as part of the fruit. But if the fruit is left on the vine until a little past the moment of maturity, it shows the property of the raspberry, leaving the receptacle on the

vine, and coming away as a cup-shaped fruit. Here, then, there is a compromise in which it may be said that each line of ancestral tendencies makes its influence felt.

In general, it may be said that this case is typical. As a rule, the different traits of plants or animals that can be interbred are not so widely divergent as to be absolutely antagonistic, and the offspring is likely to show a blending of the traits. There are numerous cases, however, in which a compromise is not so readily effected, and in which one trait or the other seems for the moment to be predominant.

As an illustration of this, take the case of Mr. Burbank's white blackberry. If this is crossed with a black blackberry, the hybrid bush will bear only black berries; the tendency of the white blackberry to reproduce itself seems entirely subordinated.

But, although for the moment subordinated, the tendency to produce white berries is not lost from the germ-plasm of the hybrid. The proof of this is found in the fact that in the next generation a certain proportion of the progeny will bear white berries. This reappearance of a submerged trait in the second and in subsequent generations furnishes one of the most striking and interesting aspects of the entire subject of heredity.

The Production of Mutants

Mr. Burbank had not proceeded far in his studies of hybridization before he discovered that the most astonishing segregation and redistribution of characters may take place in second-generation hybrids.

If he crossed two parent strains that were more or less divergent, he might find the traits of the parents variously blended in the hybrids of the first generation, but if he interbred these hybrids, he was almost sure to get in the next generation a conglomerate fraternity, showing the traits of the grandparental forms reassorted into almost every imaginable combination. More than that, there were likely to appear forms that diverged markedly from either of the grandparents.

It would seem that the mingling of divergent germ-plasms had made possible the rejuvenescence of ancestral traits that had long been submerged.

Mr. Burbank found that by carefully inbreeding individuals that showed the new or revived trait, he could accentuate the quality and in many cases produce new varieties so markedly different from either of the grandparental forms as to justify his use of the term "new creations."

The only plausible explanation of such an-

omalies is that the qualities thus newly revealed and accentuated were traits that had been manifested by remote ancestors, but which had been subordinated and submerged through conflict with other more or less antagonistic traits in the ancestral germ-plasm.

So striking were the modifications that Mr. Burbank was thus enabled to produce at will through the hybridizing of divergent forms that he came to feel confident of being able to modify almost any form of plant life, and produce striking new varieties, provided an allied form could be found with which hybridization could be effected.

When the celebrated Amsterdam botanist, Professor Hugo deVries, came forward with his theory of mutation, according to which a form of plant life may now and again diverge radically from its parent forms through "spontaneous" variation, constituting a new form of "mutation", Mr. Burbank was first to assert that much mutant forms were explicable as due to hybridization.

He asserted that he himself produced mutations at will through hybridization, and the long list of his plant developments afforded striking verification of his claim.

More than this, Mr. Burbank's experiments led him to believe that hybridization takes place

among plants and animals in a state of nature much more commonly than had hitherto been supposed, and that such hybridization is often responsible for the production of new forms that may play an important part in the scheme of evolution. He believes, indeed, that hybridization largely accounts for the origin of those variations which Darwin had been content to speak of as "spontaneous", and which are recognized as the material with which natural selection works in developing new species.

Mendelian Heredity

The striking results in the production of new varieties through hybridization that Mr. Burbank had attained became known to horticulturists and biologists, and probably had an important share in preparing the world to look with interest on the experiments of the Austro-Silesian monk, Mendel, when the obscure report that this experimenter had published as long ago as 1863 was rediscovered just at the close of the nineteenth century.

Mendel, working chiefly with the garden pea, had paid attention (as we have already seen) to a few conspicuous characters regarding which different races of garden peas differ. ,

He had observed the mutual relations in the inheritance of such qualities as tallness versus

shortness of vine, pinkness versus whiteness of flower, yellowness versus greenness of pod, etc., and had traced very definitely and with scientific precision the relations of these qualities in cross-bred plants of the first and second generations. In so doing he reduced to a definite formula the observation of the mingling of traits in the first generation and their redistribution and recombination in the second, which Mr. Burbank had observed to be so common a phenomenon with the great number of species with which he worked.

But Mendel went farther. He formulated a theory as to the causes that operate to determine the relations of antagonistic characteristics when brought together through the mingling of divergent germ-plasms; and his theory was at once so simple and so satisfactory that it came to be accepted at least as a provisional hypothesis everywhere.

According to this theory, every tangible characteristic of any organism is determined by the mingling in the embryonic germ-plasm of two hereditary "factors" or "determiners", the juxtaposition of which is essential to the production of the character in question. If these factors represent the same quality, there will, of course, be no antagonism, and the quality of the resulting character will not be in doubt. But, on the

other hand, the two factors are antagonistic—one, let us say, representing a black berry and the other a white berry—the result may be that one factor entirely dominates the other, the subordinated character seeming to have no representation whatever.

But the factor thus submerged reproduces itself and distributes its representatives in the germ-cells of the next generation quite as freely as does the dominant factor. So there is an even chance that factors of the subordinate type will be represented in the germ-cells that are to produce progeny of a second generation.

According to the mere theory of chances, if we mix together indiscriminately a quantity of black factors and white factors in equal numbers, and pick out pairs of factors at random, it must result that in any *average* group of four pairs we shall find one pair of black factors, one pair of white factors, and two pairs of mixed factors.

If you will experiment with checker-men, drawing them in pairs from a mixed lot, you will be surprised to find how generally you approximate the formula, even when small numbers are in question.

Nature's Game of Chance

According to Mendel's interpretation, nature performs such an experiment whenever two germ

cells bearing antagonistic factors have come together, and the results of her game of chance are seen in the phenomena of what have come to be spoken of as Mendelian heredity.

Tangibly illustrated, the result is that when, for instance, a pea having a tall vine is crossed with one having a short vine, the offspring will be tall; but *their* offspring will be represented, on the average, by one tall vine (pure dominant) that will breed absolutely true; one short vine (pure recessive) that will also breed absolutely true; and two tall vines (mixed) that will not breed true because they contain factors both of tallness and of shortness.

The essential truth of the Mendelian formula has been demonstrated by thousands of observations, but a good many workers who have observed its application in simple cases have failed to realize the true bearing of the phenomena. The truth seems to be that it is only the comparatively superficial and newly acquired characteristics of any organism that still have sufficient flexibility to be experimented with by Nature in this game of chance that we speak of as Mendelian heredity.

Stated otherwise, what we term Mendelian inheritance appears to be Nature's method of testing out new qualities that are from time to time impressed on the organism through the influence

of environment.

Some individuals of a certain strain of plants or animals chance to be subjected to influences that modify somewhat the color of flowers, the texture of hair, the size of body, or what not. An individual of this modified race presently interbreeds with an individual not so modified.

The important question is this: Is the modification beneficial to the species or otherwise?

The matter is put to an impartial test through the operation of Mendelian heredity.

All the immediate offspring present tangibly the modified character, but the unmodified character is given a hearing again the next generation. And if the modification is neither favorable nor unfavorable to the race, it may chance that two varieties, one showing the modification and the other without it, will continue to flourish in the same environment.

As a typical instance — taken at random — you may find gray screech-owls and red ones in the same brood.

If, however, the modification is favorable, the individuals possessing it will ultimately prevail over those lacking it, and it will be added to the regular equipment of the species. If, contrariwise, the unmodified character was better adapted to meet the requirements of environment, it will pre-

vail, and the individuals having the modification will be weeded out.

A pure "recessive", as we have seen, carries no factors for the antagonistic "dominant" quality. Thus it may come about that certain traits of a given organism are absolutely eliminated from the germ-plasm of a fixed proportion of the descendants of that organism. Thus — anomalous though it seem — an individual may be of "pure" strain notwithstanding the fact that one of his grandparents was of different strain; and the known laws of heredity explain the anomaly.

This is the one really new conception in the present-day interpretation of the laws of heredity. The older idea was that any trait once impressed on the organism remains forever as a latent character in the germ-plasm, and is susceptible of being made tangible in some of the progeny under favorable conditions.

The laws of Mendelian inheritance show us that the factors of heredity may be so re-distributed that individuals of the same parentage, and hence precisely the same heredity, broadly speaking, are radically different in their innate hereditary tendencies as regards some minor but perhaps not inconsequential qualities.

The new knowledge does not controvert the old rule that "like produces like", but it gives us

new insight into the interpretation of that rule. In its practical bearing on the interpretation of heredity as applied to human beings, the new knowledge takes precedence in importance over all that has hitherto been known about heredity.

Until the Mendelian interpretation was available, no one could pretend to fathom the mysteries of atavism, much less to predict as to the probable recurrence of submerged ancestral qualities in any given generation.

But the Mendelian formula serves as a working hypothesis that enables us in many cases to predict with a fair degree of certainty what will be the result of the union of individuals of known heredity.

Thanks to this hypothesis, however, the laws of heredity in their application to the human organism now take on a definiteness that they hitherto have lacked.

We shall have occasion to note specific instances of their application to a wide range of cases in succeeding monographs of this series.

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